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THE PLANT DISEASE REPORTER

Issued By

PLANT DISEASE EPIDEMICS
and
IDENTIFICATION SECTION

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

NEW DEVELOPMENTS AND NEW PROBLEMS CONCERNING NEMATODES IN THE SOUTH

Supplement 227 October 15, 1954

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The Plant Disease Reporter is issued as a service to plant pathologists throughout the United States. It contains reports, summaries, observations, and comments submitted voluntarily by qualified observers. These reports often are in the form of suggestions, queries, and opinions, frequently purely tentative, offered for consideration or discussion rather than as matters of established fact. In accepting and publishing this material the Plant Disease Epidemics and Identification Section serves merely as an informational clearing house. It does not assume responsibility for the subject matter.

PLANT DISEASE REPORTER SUPPLEMENT

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PLANT DISEASE EPIDEMICS AND IDENTIFICATION SECTION

Horticultural Crops Research Branch Plant Industry Station, Beltsville, Maryland

Papers From The Symposium On

NEW DEVELOPMENTS AND NEW PROBLEMS CONCERNING NEMATODES IN THE SOUTH

presented at the Dallas meeting
Southern Division, American Phytopathological Society
Dallas, Texas, February 1-3, 1954

Plant Disease Reporter
Supplement 227

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PLANT NEMATOLOGY: SCIENCE OR SERVICE?

Eldon J. Cairns

Confronting the at present relatively few plant nematologists is a dilemma that should be recognized by all concerned with plant nematodes. The phytonematologist finds that increased requests for more research and for more service create a predicament for him. If he devotes most of his time to the service demands, it is at the expense of his own research. Service work does render valuable assistance to the research activities of others, aids plant growers, and promotes interest in and support for Plant Nematology. If, on the other hand, the nematologist devotes most of his time to the pressing research problems, for which he is specially trained, he does so at the expense of the service requests.

In the past, the dilemma of "Plant Nematology: Science or Service?" has been resolved by compromise, with a strong tendency towards service. This course of action is probably the major reason for the increased awareness of the importance of plant nematodes as an adverse factor in plant production. Service work has made it possible for the few plant nematologists to gain a practical evaluation of the nematode situation on a national and, to some extent, international scale. Service work is of great value in obtaining knowledge as to the distribution of species and the development of epidemics and leads to the discovery of new forms. Service work to regulatory agencies gives definite information on the modes and extent of dispersal of nematodes as the result of man's activities. Service work also enables the nematologist to keep in touch with the associations of nematodes with plant disorders wherever plants are grown for pleasure or profit.

The present-day situation is intensifying the dilemma. There is the same, but increasing, service responsibility as more growers and allied research workers become concerned with nematodes. In addition, there is now an increasing obligation to do research. This has come with the admission that appreciable further progress in plant nematode control is dependent upon more research. Any compromise solution of the nematologist's dilemma has now to provide for the needed science.

Obviously, the ideal condition is "Plant Nematology: Science and Service"; it cannot be simply one or the other. However, to the person confronted with the increasing demands for Science and Service, whether he can do both well is becoming an issue. But is it realized that the decision is a matter of concern and is, in part, dependent upon the growers and research workers of the Southern Region? The answer is yes, because the Southern Regional Nematode Project is an outcome of the recognition by these groups of the nematode problems. Under this Regional Project nematode research centers were recently established at Raleigh, North Carolina and at Auburn, Alabama. The nematologists starting these centers face the problem of developing a high output of both Science and Service.

The phytonematologist recognizes the need for giving service and understands its value in assisting the research of others working with nematodes; he is desirous of continuing it as a part of his job. At the same time he is aware of the needed basic research to which he wants to contribute. Furthermore, the nematologist appreciates the sometimes overlooked fact that the service he renders others can be no wider in scope or more valuable than its scientific basis. For example, a routine service diagnosis is no better than the accuracy of the identification and the adequacy of the sample. Furthermore, an identification is of little value unless it can be put to use. Plant Nematology as a Service will become more worthwhile when, after examining representative samples, we can better answer such questions as the following: Are the nematodes involved able to cause plant losses? Which kinds of plants will suffer and to what extent? What will be the chances of finding a resistant crop variety? What will be the influence of such ecological factors as location, climate, soil type and condition, and the associated soil microorganisms? The nematologist does not want to avoid giving Service. However, he is concerned by the realization that the same amount of routine work could produce greater value if the foundation of scientific knowledge were more extensive.

How can the nematologist's dilemma be resolved so that he can conduct needed basic research without drastically reducing service? Seemingly a realistic solution involves the cooperation of those requesting service and the training of more workers in nematology.

At present, the nematologist must have more time for research. How can he get it? The most frequent and probably the most time consuming type of service request is for identification of nematodes in soil and plant samples. Considerable time could be saved if the samples sent to the nematologist arrived in better condition and were more representative. Such samples are easier to process and will yield more information. Soil and plant samples are best when col-

lected and shipped in moisture-proof wrappings such as plastic or waxed-lined bags. A composite of several samplings will be more representative than a single sample. Remember, too, that active, motile nematodes, if obligate parasites, will have left host tissues showing obvious necrosis.

In the future, time for research would be increased if more people were trained in the methods of nematology. Many persons, if instructed, would be able to do some of their own nematode service work. Some workers have been doing it, and all who learn to examine their plant material and identify the nematodes present will find it an advantage in their research. No involved or lengthy training is needed for any interested person to become competent in using the relatively few and simple techniques of plant nematology. In the near future instructional aids such as manuals, simpler generic keys, and possibly occasional short courses in practical nematology should be made available. Special efforts should be made to provide advanced training for those who want to specialize. At present, some graduate course work in plant nematology is available at North Carolina State College of Agriculture and Engineering and at the University of California. Another possibility which has been successfully operating for the Section of Nematology of the United States Department of Agriculture is on-the-job training with the cooperation of nearby universities. Having more people trained in plant nematology can be of such great mutual benefit that providing opportunities for training should become a recognized part of any Regional Nematode Project.

NEMATOLOGY SECTION

NEMATODES AS POSSIBLE MEMBERS OF DISEASE COMPLEXES INVOLVING OTHER PLANT PATHOGENS

Q. L. Holdeman

A survey of the literature reveals numerous reports on the association of nematodes with the increased severity of diseases attributed to other causes. Most of these reports are based on observations and on indirect approaches to the problem. Very little has been published on experiments that would definitely demonstrate the influence of nematodes. New advances in techniques offer an opportunity to study and to demonstrate a definite relationship, if any. A brief summary of the problem at this time may serve to point out needed research.

COTTON -- Fusarium Wilt. As early as 1892, Atkinson (3) in Alabama reported that root knot and wilt (Fusarium oxysporum f. vasinfectum) were distinct diseases, but when both attacked the plant, the condition of the plant was much more serious.

In the late twenties and early thirties when wilt-resistant varieties of upland cottons were released and grown in widely scattered locations, it was found that varieties were resistant in one location but might show a high percentage of wilt in another. Again, the attention was focused on nematodes. The nematodes that have been reported associated with the occurrence of severe wilt include root knot (Meloidogyne sp.), meadow (Pratylenchus (?) pratensis), and the sting nematodes (Belonolaimus gracilis).

The use of nematocides added evidence to the role of the nematodes. It was observed that fumigation of the soil to control nematodes reduced the incidence of Fusarium wilt on resistant varieties.

In 1941, Smith pointed out that cotton varieties combining root knot and wilt resistance were required for Coastal Plains conditions. More recently, Smith and Dick (15) reported that resistance in upland cotton to Fusarium wilt is apparently determined by a single dominant factor. The ability of a variety to survive in the field would depend largely on the number of factors for nematode resistance inherent in the variety.

Although circumstantial evidence was strong, definite laboratory demonstration of the role of nematodes has only recently been presented. Although Arndt and Christie (1) obtained negative results with their greenhouse experiments involving four free-living nematodes, Holdeman and Graham (8) were able to demonstrate a relationship between the sting nematode and the increased incidence of wilt on a wilt-resistant cotton. To date, the relationship of root knot and meadow nematodes to the increased severity of wilt has not been demonstrated.

The nematodes' mode of action in increasing the severity of wilt is not fully understood. It has been mentioned that root knot larvae macerate the root tips and cause cracks that extend into the differentiating tissue, thus offering a portal of entry. In some instances, nematodes inject salivary secretions into the root cells, probably causing some damage other than mechanical penetration of the cells.

The effect of nematode damage to the root system on the uptake of nutrients should be considered. In some non-fertile fields, it has been demonstrated that the application of potash to the soil reduced the amount of wilt (21). It is of interest to note that Oteifa (12), working with Lima bean, was able to overcome some of the growth reduction caused by the root knot nematode (M. incognita) by increasing the amount of potassium in his nutrient solutions.

In their experiments with the sting nematode, Holdeman and Graham observed that surviving plants of both wilt-resistant and of susceptible cottons usually had one or more roots that "escaped" to the side or to the bottom of the pot and developed normally. This suggests that the increased incidence of wilt was probably due to the severity of the damage and to the ability of the nematode to eliminate the effective root system.

Under field conditions where nematodes are the main factor, the wilt can be controlled without rotation by combining soil fumigation with the use of a resistant cotton variety.

TOBACCO -- Black Shank: Tisdale (17) in Florida indicated that injury caused by the root nematode (Meloidogyne sp.) may affect the degree of resistance of tobacco to black shank (Phytophthora parasitica var. nicotianae). A report from North Carolina (11) stated that fumigation had little effect on black shank development on susceptible varieties; however, on resistant varieties, black shank development was delayed and was less severe. More recently, it has been demonstrated that root knot nematodes (Meloidogyne spp.) increased the expression of black shank on a resistant tobacco variety (13).

The present level of black shank resistance is not high enough to permit continuous crop-

ping of tobacco on severely infested land even when fumigation is combined with the use of a resistant variety.

TOMATO -- Fusarium Wilt: Based on field observations, Young (19) in Texas suggested that a root knot nematode increased the severity of wilt (F. oxysporum f. lycopersici) on tomato. Also (6), there was less wilt on the Marglobe tomato following a resistant crop of peanut (33.5 percent) than following root knot susceptible cowpeas (85 to 95 percent). Using carbon disulfide as a soil fumigant, Young (20) controlled root knot nematode but did not control the wilt.

In greenhouse tests in Beltsville, McClellan and Christie (9) were unable to demonstrate any influence of root knot nematodes on the incidence of tomato wilt.

OTHER SOIL-BORNE FUNGUS DISEASES: A report from Georgia (5) states that D-D and ethylene dibromide treatments have consistently controlled southern stem rot and root rot (Sclerotium rolfsii) on tobacco. These fumigants have also given partial control of fusarium wilt (Fusarium oxysporium f. nicotianae).

Soil fumigation for sweetpotatoes controlled nematodes, wireworms, and black rot (10).

MEADOW NEMATODE AND ROOT ROT: Observations on roots of different plants that are attacked by nematodes reveal that the different crops vary greatly in their reactions. Roots of some plants break down rapidly following attack, while roots of other species remain apparently sound. Hastings and Bosher (7) studied the association of the fungus Cylindrocarpon radicicola and a meadow nematode. On some of the plant species they found that there was a greater reduction in plant growth when both organisms were used in combination than when either was used alone. The data are not clear as to how many plants or replications were used in the test.

DEFICIENCY DISEASES: Chitwood, et al., (4) reported that various nematodes were associated with the decline and chlorosis of peaches. Chlorosis appeared to be due to a deficiency of magnesium or iron or both. It is logical to suspect that the interference of nematodes may be a factor in some cases where woody plants are slow to respond to soil applications of the deficient elements.

In South Carolina in 1952, observations made on soybeans growing on sting nematode-infested fields revealed that 90 percent of the plants showed severe symptoms of iron deficiency. In a second field observed in 1953, soybeans grown on land infested with an undescribed nematode showed nitrogen deficiency symptoms. An examination of the roots revealed root rot accompanied with an apparent reduction of nodulation in deficient areas.

WHEAT -- Dilophospora Disease: Most of the attention has been focused on soil-borne diseases. The work of Atanasoff (2) showed that nematodes might also be a factor in leaf and stem diseases. Working with the fungus Dilophospora alopecuri, and with the wheat gall nematode, Anguina tritici, Atanasoff found that he was able to reproduce the Dilophospora disease when he inoculated plants infected with the nematode. Inoculations with the fungus alone failed to produce the disease. He also observed that further spread of the disease stopped when the plants with the nematode died out or formed galls.

Recently, Johnson and Leukel recorded the association of the fungus and the nematode on wheat from South Carolina.

A similar disease relationship has been suggested for the bacterium Corynebacterium tritici and the wheat gall nematode (18).

CONCLUSION: Dr. G. Steiner of the Section of Nematology, U.S. Department of Agriculture, has frequently pointed out that soil-borne diseases are, in some instances, of complex character, and that nematodes frequently are members of such complexes, acting as initiators, cooperators, synergists, aggravators, or otherwise (16). He has suggested that nematodes may be carriers of bacteria and fungi and may possibly play a role in some of our "soil-borne" virus diseases.

Interest in the role of nematodes in our complex soil problems is on the increase. It is reasonable to expect that rapid progress will be made.

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SOUTH CAROLINA AGRICULTURAL EXPERIMENT STATION, FLORENCE, SOUTH CAROLINA

RECENT DEVELOPMENTS WITH ECTOPARASITIC NEMATODES

T. W. Graham

Among the important new developments relating to ectoparasitic nematodes is the growing recognition of the damage these pests are able to do to our crops in the South. There is no real reason why we should separate the ectoparasitic nematodes from others insofar as damage to crops is concerned, since the final effect is much the same for all nematodes. The increased recognition of nematode diseases as a factor is evidenced by the widespread increase in the use of soil fumigation. For example, in South Carolina we estimate that approximately one-half the tobacco land in the State was fumigated last year, which represents about 60,000 acres. Similar interest in soil fumigation has developed in all the other tobacco growing States in the Southeast as well as in other parts of the country.

Perhaps the most significant advance in connection with ectoparasitic nematodes is that we are learning how to recognize them and how to study their effects on plants. New techniques of study were necessary because these organisms do not penetrate roots but instead feed from the root surface and live in the soil. For this reason they are not usually found in examination of the roots, which would be the logical place to look for an organism causing a root disease. The Baermann funnel method of washing and screening soil samples is the basic step leading to better techniques in studying ectoparasitic nematodes and the diseases they cause.

Recently Dr. Christie in Florida has studied the effects of the sting nematode and the stubby root nematode, and has shown how serious these pests are on numerous vegetable crops in that area. Dr. Holdeman and myself in South Carolina have studied the sting nematode on cotton and other field crops on which its effects can be devastating. We found, also, that this nematode can live and increase on a large number of wild and cultivated plants. The same nematode has been found doing serious damage to peanuts in Virginia by Dr. Lawrence Miller. Recently we have had occasion to study the tobacco stunt nematode, Tylenchorhynchus claytoni, which is parasitic on tobacco. Another species, T. dubius, was recently reported by Dr. Reynolds in Arizona to be parasitic on cotton and beans. Dr. Martin and his associates are pointing out the nematode troubles in Louisiana. Mr. Machmer has indicated that the ring nematode is causing damage to peanuts in parts of Georgia, and we have observed this in South Carolina too, as well as ring nematode damage to tobacco.

This is by no means a complete account of active work on ectoparasitic nematodes but it does indicate the awakening interest in these important plant pests.

SOUTH CAROLINA AGRICULTURAL EXPERIMENT STATION, FLORENCE, SOUTH CAROLINA

VALUE OF GREENHOUSE TESTS IN EVALUATING THE HOST RANGE OF NEMATODES

Q. L. Holdeman

For many years, most agricultural workers in the Southeast have been considering only one nematode, the root knot nematode. Research work in recent years has shown that the root knot nematode is actually composed of a group of species. Also, other parasitic nematodes are now being recognized by agricultural workers. Greenhouse tests that have been reported in recent years have shown that these different species of nematodes have a larger host range than has been previously suspected. Also, crops loosely termed as "nematode resistant" are very susceptible to some of the nematode species or, at least, are capable of building up or perpetuating a population of a nematode that would be damaging to the next crop in the rotation.

Work with soil fumigants has shown that nematodes can be controlled successfully on some of our annual crops. However, on certain low-income crops, the added cost of the fumigant, plus the other hazards of crop production such as insects and droughts, does not allow a satisfactory margin of gain. At present, there is no chemical therapeutant that can be used to control nematodes on perennial crops. To cope with these conditions, the research worker will have to revise his approach to the problem. Host ranges of the nematodes involved will have to be studied. When the information is compiled, then the agricultural worker will be able to re-evaluate crops to be used in rotations and for orchard cover crops.

It must be realized that greenhouse tests are conducted under atypical conditions and that final conclusions cannot be drawn until actual field trials are conducted. However, greenhouse tests will give an indication of the reaction and troubles to be expected in the field.

Reports on greenhouse tests are already being published and it is expected that other research workers will become interested in such work; therefore, it seems advisable to point out some of the problems involved. Some of the factors that should be taken into consideration are discussed below.

1. Field Soil. Satisfactory information can be obtained with some naturally infested field soils if the tests are watched closely and if weed seedlings are removed promptly.

2. Influence of Parasites. The main object of such trials is to find crops that reduce the numbers of nematodes. If nematode parasites interfere with the test, no definite conclusions can be drawn until the test is repeated.

3. Influence of Temperatures. Warm temperatures are needed for maximum activity; therefore, during winter months, cold areas near the edge of the greenhouse should be avoided. Limited observations suggest that the action of certain fungus parasites of nematodes might be increased in cold soils.

4. Rate of Seeding and Type of Plant Material. In one test comparing heavy seeding versus a single plant, it was observed that the populations under the single plants reached a much higher level. In another test, rooted cuttings of sweetpotato produced a higher population than did non-rooted cuttings. The initial attack on the latter was sufficient to almost eliminate root development, thereby reducing the root area available for feeding.

5. Length of Time. The life span of some nematodes is not known. The test should last long enough to allow the nematode to increase but yet not long enough to cause the nematode to die out because of destruction of the food supply. In two tests lasting 65 and 100 days, respectively, there was very little difference in the average populations of the spiral nematode, Helicotylenchus nannus, under soybean and oat. Corn and sweetpotato yielded a higher population after 100 days, while the reverse was true for rye and barley.

6. Collection of Data. Free-living nematodes are easy to work with and may be removed from standarized samples by screening and the Baermann funnel technique. However, for nematodes with different habits, techniques may have to be modified.

7. Varieties. Named varieties that are readily available should be used, if possible. Variations in the reports of workers in separate localities might suggest race differences; also, further examination of preserved specimens kept by the respective workers might later reveal species differences.

In some cases, differences might be due to the variation in the plant material. By making single plant selections of Lespedeza sericea, lines may be obtained that are resistant, tolerant, or highly susceptible to one isolate of Meloidogyne incognita var. acrita.

Greenhouse tests should prove a valuable method for obtaining information prior to the initiation of field tests.

SOUTH CAROLINA AGRICULTURAL EXPERIMENT STATION, FLORENCE, SOUTH CAROLINA

PLANT ABNORMALITIES CAUSED BY PARASITIC NEMATODES

T. W. Graham

The most obvious and easily recognized plant abnormality caused by nematodes is stunted and unthrifty growth. This symptom no doubt is a common response to invasion by all plant parasitic nematodes; therefore, stunting is the obvious sign that leads to the detection of nematodes. The usual response to nematode attack is not early death, but rather a slow decline. For example, with perennial plants this decline may extend over a period of several years. With annuals, often by the end of the growing season few plants may have died or even have showed obvious evidence of trouble, yet the overall damage on an acreage basis is likely to be very great. This is a basic reason why the actual extent of the damage due to many of our nematode diseases is overlooked. On the other hand, there are instances where crop damage is spectacular. One of the best examples of this that I have seen is the effect of the sting nematode on cotton, where large areas of an infested field may be denuded with losses of 50 percent or more.

I think it best at this point to discuss the specific symptoms described for the various nematode diseases that have been studied. I will confine this discussion to the root symptoms, since the top symptoms are not usually distinctive in separating the kinds of nematodes involved.

The Meadow Nematode, as you know, is an endoparasitic species which enters the root while feeding and spends at least a part of its life cycle in the root tissues. It is known to lay its eggs in the roots of tobacco and corn and perhaps in other plants that it feeds on. The early symptom on tobacco is a well marked lesion on the smallest roots. These lesions are reddish-brown in color and show up in marked contrast to the white healthy roots. Later there is a generalized root decay. On corn roots this nematode produces a very different effect, i. e., the invaded roots show a water soaked area instead of a well defined lesion. These two hosts also differ a great deal in the amount of root decay following attack by the meadow nematode. Tobacco roots decay very quickly even when relatively few nematodes are present, whereas corn roots may harbor large populations yet show relatively little root decay. This difference in symptoms caused by the same nematode on different plants is cited to show the significant fact that plants may vary greatly in their response to nematode attack.

The Stubby Root Nematode has been described by Dr. Christie as causing abnormalities in root growth by injury to the root tips. Root necrosis is not extensive, at least in the early stages, although this depends to some extent on the plant attacked. In most cases the root tips turn brown, but in some plants, e. g. corn, the browning is not extensive. In later stages a considerable amount of necrosis is evident, with many roots wholly or partially killed, but this condition is probably due to secondary invading organisms. Dr. Christie describes the stubby root disease as especially damaging to the seedlings. When the seed is germinating the growing point may be attacked and killed while very short. Effects on older plants may vary considerably. If roots reach a moderate length before growth is stopped a short stubby root system may result, with sometimes slightly swollen branches giving an overall stubby root appearance.

The Spiral and Sting Nematodes. We have had occasion to study the effects of the sting nematode on cotton, soybeans, and a few other crops in some detail, also the effects of the spiral nematodes on tobacco and tomatoes. These, of course, are ectoparasitic nematodes which feed from the root surface. We have found that both the spiral and sting nematodes cause a well marked root lesion in the early stages of attack, very similar to that caused by the meadow nematode. The first evidence is a dark shrunken area at any point along the root axis or the root tip, the latter often being killed before longitudinal growth starts. With cotton or tobacco general root decay starts rather quickly and the entire root system may be destroyed before the end of the growing season. On corn affected by the sting nematode we have seen a proliferation of short roots above the point of nematode attack, which results in a so-called "witches broom." Expression of these symptoms, however, is variable, depending on the plants affected, the number of invading nematodes, and perhaps other factors.

The Tobacco Stunt Nematode, Tylenchorhynchus claytoni. Although this is another ectoparasitic species its effect on tobacco roots is entirely different from that of other root nematodes. We found that root lesions are absent and root decay does not occur; however, the roots are seriously retarded in their growth and do not elongate normally. Instead, they remain short and clumped together in a dense mass. On close examination attacked roots appear shrunken and lack the turgidity of healthy roots. In pathogenicity trials the green weight of infected roots was invariably less than that of comparable healthy roots.

SOUTH CAROLINA AGRICULTURAL EXPERIMENT STATION, FLORENCE, SOUTH CAROLINA

HYPERPLASTIC ABNORMALITIES OF ROOTS OF OATS AND OTHER CEREALS AND GRASSES SUSPECTED TO BE CAUSED BY NEMATODES

S. S. Ivanoff

This is a report on certain hyperplastic abnormalities affecting the roots of oats, barley, wheat, and some other grasses noticed in Mississippi in the spring of 1953. Some greenhouse observations are also included.

The first abnormal oat specimens were found on the grounds of the Coastal Plains Branch Experiment Station, Newton, Mississippi, adjoining a small planting of Irish potatoes which showed what appeared to be a severe case of root-knot injury. The roots of the oat plants showed slight swellings resembling root-knot nematode injury on other plants, stubby terminals with tufts of secondary roots, some of them decaying, and general stunting of the entire root system (Fig. 1). On pulling up the oat plants, the individual roots seemed encased in a fine soil envelopment. The soil type in this locality is Prentiss fine sandy loam. Further investigations on two occasions showed that oats of several commercial varieties showed these abnormal manfestations. Barley showed the abnormalities also, as well as wheat, but the latter to a lesser extent. All affected plants appeared unthrifty. Corn examined at the Station grounds at that time did not show these symptoms. Unidentified grasses showed similar abnormalities to some extent.

FIGURE 1. Left -- Stunted oat roots with swellings, suspected to be caused by nematodes.
Right -- Normal looking roots from an oat plant not showing such swellings. This plant was grown at a different location.

The general appearance of the affected roots suggested nematode injury. However, microscopic examinations did not reveal the presence of nematodes within the root tissue. Specimens of these oats were sent to Mr. A. L. Taylor, Nematologist, U. S. Department of Agriculture at Beltsville, Maryland, for a more thorough examination. Mr. Taylor stated that he found a large number of nematodes of the species Panagrolaimus rigidus around the roots and in the crowns. In the soil around the roots he also found species of the genus Dorylaimus. He did not find nematodes within the root tissue.

Cantaloupes and cucumbers were then planted in the same soil and locality where the abnormal oats were found. The cucurbit plants eventually developed typical root-knot (Meloidogyne sp.) symptoms.

Prior to the field observations, some greenhouse studies were made of injury to young oat

plants grown in nematode-infested soil. This light sandy loam was originally obtained from the vicinity of Columbus, Mississippi, and was used to grow cantaloupes. The cantaloupe plants showed slight to severe root-knot symptoms. Grass plants growing between the rows as weeds also showed slight swellings on the roots. Seeds of commercial oats were planted after the removal of diseased cantaloupe plants. After several weeks some of the young oat plants developed slight but distinct root-knot-like symptoms, including swellings on the roots, stubbiness of the roots, and tufts of secondary roots arising from stubby root terminals. Some of these root tufts showed signs of discoloration and decay. No nematodes were found inside the root tissues.

Following these observations the question may be asked: What caused the root abnormalities on the oats and on the other grasses? Two possibilities come to mind: 1) that the symptoms may have been induced by the activities of certain inadequately known ectoparasitic nematodes, or 2) that these abnormalities might have been caused by the mass action of one of the better known root-knot nematodes, the larvae penetrating the roots perhaps, but not multiplying or even surviving for any length of time within the root tissues.

DEPARTMENT OF PLANT PATHOLOGY AND PHYSIOLOGY, MISSISSIPPI AGRICULTURAL EXPERIMENT STATION, STATE COLLEGE, MISSISSIPPI

PARASITIC RACES OF MELOIDOGYNE INCOGNITA AND M. INCOGNITA VAR. ACRITA

W. J. Martin

In 1944 Christie and Albin (1) published their results showing the existence of races of the root-knot nematode, then known as Heterodera marioni. In 1949 Chitwood revised the classification of root-knot nematodes, placing them in the genus Meloidogyne and describing different species (2). Some of Christie's parasitically-different populations fitted into some of the newer species concepts.

Christie and Albin reported that certain of their populations failed to develop on cotton, variety Coker 100. Two of these populations that did not affect cotton were later placed in the species M. halpa (2).

Recently, Martin reported that certain Louisiana isolates of Meloidogyne incognita and M. incognita var. acrita failed to develop on the Deltapine 15 variety of cotton, while other isolates of this species and its variety infested and reproduced readily on Deltapine 15 (3). A summary of this data is given in Table 1.

Table 1. A summary of the development on Deltapine 15 cotton of different isolates of Meloidogyne incognita and M. incognita var. acrita from Louisiana.

Isolate	Species[a]	Development[b] on cotton
From tomato		
3H	M. incognita	-
3J	" "	-
3M	" "	-
3K	M. incognita var. acrita	-
3P	" "	-
3C	M. incognita	+
3L	" "	+
From okra		
15B	M. incognita var. acrita	-
15I	M. incognita	-
15D	" "	+
15F	" "	+
15L	" "	+
15J	M. incognita var. acrita	+
From Hairy Vetch		
28B	M. incognita	-
28E	" "	-
28C	M. incognita var. acrita	+
28D	" "	+
From Cucumber		
4A	M. incognita var. acrita	-
4D	" "	+
From Lamium amplexicaule		
31A	M. incognita var. acrita	+
31C	M. incognita	-

[a] Most of the identifications were kindly made by A. L. Taylor, Agriculture Research Service, Beltsville, Maryland. In some cases identifications were made by the writer, by determining whether the isolate did or did not infest Lycopersicon peruvianum.

[b] A plus (+) indicates development of mature females on the roots; a minus (-) indicates that mature females were not observed.

Table 2. Mean[a] rating for root galls on seven varieties of cotton with isolates of Meloidogyne incognita (3 C 4-2 and 3L) and M. incognita var. acrita (19I and 19S).

Variety[b]	Isolate and mean rating for root galls				LSD
	3C4-2	3L	19I	19S	1%
Deltapine 15	4.00	4.00	4.00	3.00	-
A.H.A. 6-1-4	4.00	3.75	4.00	2.50	0.87
Coker 4 in 1 (Strain 5)	2.75	2.75	3.00	1.75	-
Clevewilt #3	2.25	1.25	2.25	1.50	-
Greer Wichita	3.75	3.25	4.00	3.00	-
Delfos 425	3.50	3.25	-	2.25	-
Deridder Red Leaf	4.00	3.25	4.00	2.75	-
LSD 1%	1.23	1.43	0.72	1.14	

[a] Mean of ratings made on four replicates.

[b] Varieties furnished by the Department of Agronomy of the Louisiana Agricultural Experiment Station.

Table 3. Mean number[a] of egg masses developed per plant on seven varieties of cotton by four isolates of root-knot nematodes.

Variety	Isolate and number of egg masses				LSD
	3C4-2	3L	19I	19S	5%
Deltapine 15	77.0	90.5	91.8	39.3	36.40
A.H.A. 6-1-4	44.8	98.3	91.3	14.8	-
Coker 4 in 1 (Strain 5)	35.3	49.8	51.5	10.0	-
Clevewilt #3	10.0	6.8	56.3	2.0	-
Greer Wichita	84.8	130.8	74.0	24.3	-
Delfos 425	63.8	45.3	-	15.5	29.83
DeRidder Red Leaf	75.0	56.8	92.5	19.0	-
LSD 5%	47.46	72.26	-	20.62	-

[a] Mean number on roots of one plant in each of 4 replicates.

To further study the comparative parasitism of certain isolates that infested Deltapine 15 cotton, four isolates of the nematodes were placed on seven varieties of cotton in carefully controlled inoculations in 6-inch clay pots containing sterilized soil. Inoculations were made in the following manner: 50 egg masses of each isolate from tomato roots were placed in 300 cc. of water and mixed in the Waring Blendor for 30 seconds. Ten cc. of this inoculum was poured over the seed in the appropriate pot before covering the seed with soil. Four replicates of each isolate on each variety were set up in sterilized sandy loam soil. The seed were planted on April 6, 1953 and notes were recorded on June 4-5, 1953.

Strikingly uniform root knot developed on the plants in any given pot. For that reason, all of the plants in each pot were given one rating, from 0 to 4 depending upon the severity of gall development, 0 being used for no evidence of gall formation and 4 for severe gall formation. The mean rating for root galls is given in Table 2. There were significant differences between isolates on variety A.H.A. 6-1-4. Isolate 19S was different from the other three isolates. Differences between varieties of cotton were indicated with all four isolates.

Data on the number of egg masses on one plant in each pot were taken and these data are given in Table 3. Significant differences between isolates are shown on two varieties, Deltapine 15 and Delfos 425. On both these varieties the isolate 19S produced fewer egg masses than other isolates. Differences between varieties were shown with three of the four isolates, but not with 19I.

Thus, the above results show that differences in parasitism on cotton among isolates of M. incognita and M. incognita var. acrita range from no parasitism in the case of some isolates, all the way to severe parasitism in the case of other isolates.

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DEPARTMENT OF PLANT PATHOLOGY, LOUISIANA AGRICULTURAL EXPERIMENT STATION, BATON ROUGE, LOUISIANA

PROBLEMS IN BREEDING FOR RESISTANCE TO NEMATODES IN TOBACCO

T. W. Graham

Breeding work to develop disease resistant tobaccos is now actively engaged in by perhaps 12 people in the Federal and State agricultural research groups. About half of this group is interested in root-knot-resistant tobacco, which has been one of the most difficult tasks in breeding work with tobacco diseases.

Good sources of root-knot resistance from tobacco introductions and from species of Nicotiana have been used but, as yet, a high level of root-knot resistance has not been sufficiently stabilized in commercial tobaccos. There appears to be a very closely bound linkage between the factors controlling root-knot resistance and certain undesirable qualities in tobacco. Numerous lines in our breeding work have been selected with medium to high levels of resistance, but these lines almost always have been acquired by sacrificing some essential flue-cured qualities. While it would seem desirable to compromise with a medium level of resistance and a somewhat altered quality of tobacco, even this combination has not been satisfactorily stabilized. The pattern of inheritance for root-knot resistance has not been thoroughly investigated but it appears to be conditioned by multiple factors. Our experience indicates that numerous environmental factors as well influence the development of root-knot.

One of the practical difficulties in this work in the South Carolina area is the problem of keeping field plots uniformly enough infested to make critical selections. To overcome this, we are using greenhouse plantings in which we can keep soil infestation uniformly high. This procedure limits the number of plants that can be handled, but it has been a great help in making more critical selections. By using this system we now have advanced lines that show more promise of stabilized resistance.

SOUTH CAROLINA AGRICULTURAL EXPERIMENT STATION, FLORENCE, SOUTH CAROLINA

PROBLEMS ON BREEDING COTTON FOR RESISTANCE TO NEMATODES

Albert L. Smith

From the time of publication of Atkinson's (1) paper in 1892 until about 1938, the root-knot nematode was recognized as the only serious nematode problem with cotton. In the late thirties the meadow nematode, Pratylenchus pratensis, was found to be the predominant species affecting cotton in several locations. Pratylenchus was soon divided up into several species as new material was examined. Somewhat later the five species of Meloidogyne were described. This added to the confusion of the breeder and immediately the question of resistance to these new root-knot species became an important subject for investigation. Where cotton is concerned the investigation has not yet been completed. A few years later the ectoparasitic group of nematodes were found affecting cotton. Trichodorus and Belonolaimus appear to be the most serious of this type. There are of course a number of additional species affecting cotton which may or may not be serious problems for the future. However, it is apparent that new nematode problems on cotton are being found faster than old ones are being solved. Much work will necessarily have to be done before the distribution, relative abundance, symptoms produced by different species, life histories, and many other factors are determined. The possibilities of breeding for resistance to the newer types can be determined only after some of the many preliminary problems have been studied.

The problem of breeding for nematode resistance cannot be considered without giving attention to the nematode-Fusarium wilt complex on cotton. Atkinson (1) first recognized this relationship in 1892 in the first published description of the two diseases. The complexity of the problem is such that it is still not fully understood. However, two facts concerning the wilt-nematode relationship appear established which give a partial understanding of the situation:

1) -- The wilt pathogen (Fusarium oxysporum f. vasinfectum) is dependent on nematodes for entrance to the vascular system of the cotton plant. Apparently any one of several species can and do provide this means of entrance for the wilt pathogen.

2) -- The effect of nematodes on host susceptibility to wilt is a continuing one in later stages of plant development. This results in increased wilt susceptibility with increased nematode effect. Such a relationship can be demonstrated by the significant positive correlation obtained between root-knot susceptibility and wilt susceptibility, wilt susceptibility being the dependent variable.

With this understanding of the problem it is apparent that nematodes play the dominant role in the wilt-nematode complex, by first making an opening for the wilt organism and then by increasing the susceptibility of the host. From the disease loss standpoint the loss from Fusarium wilt may now be assigned indirectly to nematodes. When this loss from wilt is combined with the direct loss in yield from nematode effect then nematodes may be considered as the major cotton disease problem of the lighter soils of the rainbelt and of the lighter soils of the irrigated regions.

The root-knot nematode is still considered the major pest of cotton although other species may locally become predominant and cause greater losses. Consequently the greatest immediate benefit from a breeding program for nematode resistance appears to be in the improvement of root-knot resistance. The present level of root-knot resistance in commercial cottons is shown in Table 1. In this table the varieties are grouped on a basis of parental origin. The Clevewilt group, consisting of Coker 100 Wilt, Stonewilt, and Plains, in addition to Empire, are the major varieties planted on nematode- and wilt-infested soils. The newly released Auburn 56 variety derived from Cook 307 is far superior in both root-knot resistance and the correlated Fusarium resistance. Studies at Tallassee, Alabama, show the Clevewilt group of varieties could be improved in yield 25 percent by using Auburn 56 resistance and Empire could be improved in yield 35 percent in the same manner. As a practical approach to the problem it is suggested that Auburn 56 resistance might be utilized in initiating new crosses to improve established varieties.

The overall root-knot resistance of the most resistant variety of upland cotton is actually only 30 percent of total resistance, or absence of root-knot galls, as determined by the root-knot index method. Actually this resistance might be classed as only a moderate degree of tolerance. A rather wide search has been made through the species, subspecies, and numerous varieties of cotton for a better source of root-knot resistance. Thus far the most prom-

Table 1. Percentage of wilt, reaction to root-knot, and yield on untreated and row-fumigated soil, of 23 commercial cotton varieties. Varieties are grouped according to parental source of nematode and Fusarium resistance. Tallassee, Alabama. 1953.

Source of resistance[a]	Wilt percent	Root knot index	Acre yield lint		Increase from treatment	
			untreated	treated	Pounds	Percent
Cook 307	9.6	73.4	671	790	119	17.7
Cook 144	29.1	79.9	568	741	173	30.5
Clevewilt	31.7	87.2	542	735	193	35.6
Empire	38.7	89.4	500	777	278	55.6
Fusarium susceptible	78.6	97.3	235	564	329	140.0

[a] Varieties included in the above groups are as follows:
Cook 307: Auburn 56-7, 24 and 33.
Cook 144: Smith 78, Smith 78-25, and H81.
Clevewilt: Coker 100 Wilt, Plains, and Stonewilt.
Empire: Empire, All in One Cross, and Bobshaw-Hybrid.
Fusarium susceptible: Deltapine 15, Stoneville 2B, and Miller 610.

[b] Soil row-treated with 2 gallons of Dowfume W85 per acre.

ising material found is a wild cotton, Gossypium barbadense var. darwinii. This cotton, although short-day sensitive and hard seeded, crosses readily with upland. The evidence obtained in early crosses suggests that root-knot resistance is inherited recessively and may be polygenic. Thus it is obvious that many generations and much time will be involved in transferring such resistance to upland. However, a considerable improvement in yield on nematode-infested soils would be expected from the improved root-knot resistance. An estimated 30 to 40 percent improvement in yield is considered possible with the Clevewilt group of varieties, should maximum resistance be achieved. The differences in yield between the varietal groups on treated and untreated soil in Table 1 indicate the amount of improvement possible to attain. Observations indicate that some improvement in resistance to other nematode species would occur with improved root-knot resistance.

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ALABAMA AGRICULTURAL EXPERIMENT STATION AND FIELDS CROPS RESEARCH BRANCH, U. S. DEPARTMENT OF AGRICULTURE

BREEDING SWEETPOTATOES FOR RESISTANCE TO THE ROOT-KNOT NEMATODE

H. B. Cordner, F. Ben Struble, and Lou Morrison

The common root-knot nematode (Meloidogyne incognita (Kofoid & White) Chitwood) is one of the most serious problems in growing sweetpotatoes. When this crop is grown in infested soil, some reduction in yield is inevitable; the roots may be largely unfit for market and are entirely useless as seed. The infected plants which result when diseased seed stock is used to propagate the sweetpotato crop are most effective in introducing root knot into cultivated fields.

At a relatively early date, root-knot injury to sweetpotatoes was observed and varietal differences reported (5, 4). In these studies, the varietal differences described were based on injury to plants in infested plant beds and plant and root injury in crops grown in infested field plots. In a more recent report (3), varietal resistance to root knot was based on the prevalence of egg masses on roots of plants grown for a short period of time in infested soil in greenhouse benches. In this report, it was indicated that the Jersey varieties were the most consistently resistant, the Porto Rico variety and its mutant strains were of intermediate resistance, while the Nancy Hall and Red Bermuda were highly susceptible to root knot. Breeding line and Plant Introduction sweetpotatoes were also tested and each assigned to one of the three resistance classes.

Work at the Oklahoma Experiment Station

In a study reported in 1953 (2), it was found that resistance to root knot in sweetpotato (and also tomato) relates to the rather extensive necrosis of root tissues which occurs when the nematode larvae are present in the roots. The larvae appeared to enter the root tips of susceptible and resistant sweetpotato varieties in equal numbers, but few nematodes developed to egg-laying maturity in roots of the resistant varieties.

The reaction of a number of breeding lines and sweetpotato varieties to root knot was reported in 1951 (1). In these studies (and those to be reported at this time) the plants of the test varieties and seedling lines were grown and observed in special field areas which show uniform distribution of the root-knot nematode. The classification of the varieties with reference to nematode resistance is based on the injury to the underground portion of the plant at harvest time (hill index) and the number of nematodes found in the storage roots. This preliminary study indicated that the Jersey variety, Orlis and other parent lines, might be used effectively in breeding for root-knot resistance.

As the breeding program has continued at the Oklahoma Station, the sweetpotato varieties and breeding lines serving as parents have been carefully tested and classified according to the degree of root-knot resistance. Similarly, large seedling populations were tested as F_1 individuals. In three years about 1400 of these F_1's were tested as first year plants (direct from seed) and many others as seedling clons. The results of these tests indicate that root-knot resistance is of high frequency in seedling populations from selected parents.

When a resistant parent is crossed with a resistant parent about 50 percent of the offsprings are resistant to root knot, about 30 percent are of intermediate resistance, and about 20 percent are susceptible. The individuals from the R x S parentage are about equally distributed in the resistant, intermediate, and susceptible classes. When two susceptible parents are crossed, the offspring show about a 10 percent, 25 percent, and 65 percent distribution in the R, I, and S Classes respectively.

The resistant parents referred to in this discussion are Orlis, Nemagold (Okla. 46), E 7, and eight Oklahoma breeding line sweetpotatoes. The resistance tests with named sweetpotato varieties confirm previous reports which indicated that the Jersey varieties are resistant, the Porto Rico types intermediate in resistance, and the Nancy Hall types are susceptible. In addition, this study has shown that Heartogold, Nemagold, and breeding lines B 5999, B 5941 (USDA), and E 7 (South Carolina) are resistant. Susceptible varieties are Allgold, Redgold, Earlyport, Vates Golden, and Virginian. When the varieties in the Jersey group are considered, the mutant Maryland Golden appears to be susceptible, although its parent, Big Stem Jersey, is resistant. Similarly, Orange Little Stem appears to be less resistant than the original Yellow Jersey or the related mutant varieties Orlis and Rols.

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OKLAHOMA AGRICULTURAL EXPERIMENT STATION, STILLWATER

FUMIGATION: THEORY AND PRACTICE

Albert L. Smith

The question concerning the recommending of soil fumigants to cotton growers in Alabama has been debated since 1947, when the effectiveness of these materials for controlling wilt and nematodes and for improving yields was first determined. The questions involved were economics and the extent of the need for nematode and wilt control. At that time the yields were much more erratic due to the boll weevil situation. The development and use of the newer insecticides has stabilized yields in proportion to the ability of the growers to learn how to apply them properly. Although the average yield of the Alabama cotton crop is still less than 300 pounds of lint, many growers are confident of their ability to produce an average of a bale or more per acre. With production and price more stabilized it now appears more economically feasible to introduce soil fumigation as a cultural practice. In addition, the incentive to obtain higher yields on alloted acreage reduces grower resistance to experimening with a new and expensive operation. With the finding of many new species of nematodes attacking cotton and with losses apparently increasing and becoming obviously quite serious in localized instances the needs for fumigants are no longer questionable. Rather, fumigation is becoming a matter of necessity in some instances.

The question of equipment should be considered first. In view of the small size of farms in Alabama and the spotted nature of most wilt and nematode infestations there is need for inexpensive equipment to treat small areas. Fortunately the tobacco workers have pioneered in the development of equipment consisting of tanks with gravity flow apparatus. This equipment appears more practical for the majority of growers than the more expensive pressure system. Gravity tanks used in combination with the narrow feet developed for application of liquid ammonia and fitted on a one or two-row tractor should prove satisfactory. Difficulty has been experienced in using gravity flow to obtain the 2-gallon rate of application of Dowfume W 85. A more satisfactory flow of the liquids was obtained with Dowfume W 40 and DD applied at the 7- to 10-gallon rates per acre.

Annual row application appears necessary for cotton. Experiments indicate that the carryover value of row application is negligible when the soil is disked or plowed and rows are remade. The rush season on a cotton farm comes just before planting, consequently the application of fumigant and fertilizer may be combined into one operation or the fertilizer may be applied at time of planting. Experiments indicate that some risk to the stand is involved by planting at the time of application of fumigants, although yields have not been lowered because of reduced stands at the rates recommended for cotton. It is believed, however, that the period of waiting after planting may be safely placed at five to seven days rather than the ten days to two weeks generally recommended for other crops.

Limited experience with field application of fumigants indicates many opportunities for failure to obtain satisfactory results. Some of these involve poor methods, such as too shallow placement, failure to firm the soil properly and promptly, and application when the soil is too moist or too dry. Planting on a loose seedbed caused by deep application with later settling of the soil and burying of the seed too deep is another hazard. Seasonal effects on the crop or nematode population, or both, may give completely negative yield results from treatment. It is anticipated that growers will rapidly learn, with a few years experience, the factors involved in application of fumigants to obtain satisfactory results.

ALABAMA AGRICULTURAL EXPERIMENT STATION AND FIELD CROPS RESEARCH BRANCH, U. S. DEPARTMENT OF AGRICULTURE, AUBURN, ALABAMA

SOME PRACTICAL ASPECTS OF SOIL FUMIGATION

C. W. McBeth

The use of soil fumigants for control of plant parasitic nematodes and other pests has grown at a prodigious rate during the past eight to ten years. Due to the high cost and difficulties associated with the use of available materials, soil fumigation was confined to greenhouse and nursery before the discovery of D-D[1] (dichloropropene-dichloropropane) and EDB (ethyl dibromide). In Hawaii no pineapple is planted without first fumigating the soil. In the United States, the major portion of soil fumigants are being used as preplant treatments for tobacco, cotton, and vegetables. In some areas, large amounts of fumigants are being used as preplant treatment for perennial crops such as citrus, peach, almond, walnut, and grape. To date, there is no chemical on the market that can be recommended for treating living plants for control of nematodes. Both D-D and EDB have been used experimentally, but the margin of safety is quite narrow for either material.

Desirable Qualities of a Nematocide

Certain workers have stated that the ideal soil fumigant should be toxic to nematodes, fungi, weeds and weed seeds, but not harmful to living plants. This of course is not possible because if a material is toxic to weeds it is probably also toxic to other plants. The ideal fumigant then would be one that is toxic to nematodes and fungi, but not toxic to plants. Even this, at present, seems to be too broad, as in general, most chemicals that are highly toxic to fungi are also toxic to plants. Therefore, rather than looking for a universal fumigant, it will probably be more profitable to look for a material that will do one thing well. The ideal nematocide as we define it, would be one that is highly toxic to nematodes and relatively non-toxic to plants. Even this appears to be a rather tough problem but is probably more nearly possible than the finding of a non-phytotoxic combination nematocide-fungicide.

To be an effective nematocide, a chemical must not only be toxic to nematodes but it must be capable of dispersing itself thoroughly in the soil. Nematodes are very small worms and do not move readily through the soil. In fact some forms, such as cyst nematodes, are primarily in a totally immobile stage at the time fumigation is ordinarily done. Plant parasitic nematodes are distributed throughout the soil from the surface to several feet deep depending on the root systems of the crops that have been grown. Root knot nematodes have been found down to 3 feet on alfalfa and 5 to 6 feet on peach roots.

With our present methods of application, a soil fumigant should be volatile, with sufficient vapor pressure to spread laterally 6 to 8 inches through the soil from the point of injection. Even though a non-volatile material is highly effective, it is almost impossible to mix it thoroughly with the soil to more than 6 to 8 inches in depth. 1, 4-dibromobutene is a good example of this type of material. Thorough mixing with the soil of 75 to 100 pounds per acre will control nematodes down to 1 foot depth, but it is not practical to attempt a thorough mix to that depth on a field scale.

A residual material would be highly desirable providing it is non-phytotoxic, although it would probably have the disadvantage of having to be mixed with the soil because a volatile material would probably not stay in the soil for long periods. Even with D-D and EDB, which have very little residual nematocidal value, damage sometimes results to crops planted too soon after treatment.

Mode of Dispersion of Fumigants

Although the manner in which volatile chemicals disperse through the soil is not thoroughly understood, the movement is almost certain to be in the vapor phase following the laws of diffusion. The rate of diffusion is determined by the vapor pressure of the chemical.

Chitwood[2] states that soil fumigants tend to saturate the soil moisture in their vicinity before moving further. This would indicate that the vapor moves in the water phase and, therefore, fumigants highly soluble in water would not move far in the soil without using excessively

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1 Trademark Registered

2 Chitwood, B. G. Nematocidal action of halogenated hydrocarbons. Paper given at meeting of American Chemical Society, September 3-8, 1950, Chicago, Illinois.

high dosages. D-D, which is soluble to .1% (1000 ppm), moves quite readily in soil except where excessively high moisture is present. This, we believe, is due to reduction of porosity rather than its water solubility.

Factors Affecting the Activity of Soil Fumigants

There are at least five important factors which affect the activity of soil fumigants. These factors are discussed under the respective headings although not necessarily in the order of importance.

1. Soil Temperature -- The ideal temperature for application of any one fumigant is dependent upon the boiling point and vapor pressure. In general, the higher the temperature, within limits, the more effective the fumigant. Of course, if the temperature is too high, the vapor escapes from the soil too soon to effect a kill or to give a thorough fumigation. In general, our experience has shown that chemicals with a boiling point of 150° to 200°C are most effective at a temperature of 80°F (27° C) or higher. In controlled temperature tests these materials have been almost non-effective at soil temperatures of 50° F or less. The time required for D-D with boiling point of 130° C to diffuse 6 inches in a sandy soil is less than 24 hours at 75° F and 96 hours at 45° F. At low temperatures, high boiling point materials volatilize so slowly that a lethal dosage is not built up, or the chemical breaks down before it has had time to diffuse thoroughly.

2. Soil Moisture -- Soil moisture can be very critical in the dispersion of soil fumigants. In our work, we have found that some moisture is desirable but that it should be less than field capacity. Our experience has shown that with sandy, sandy loam, or clay loam soils, the moisture should not be more than 85 percent of moisture equivalent (field capacity) or less than 50 percent of moisture equivalent. Apparently, a higher percentage of moisture reduces the pore space in the soil and interferes with dispersion. Too dry soil allows the fumigant to escape without complete diffusion, or, according to unpublished work of Crafts and our own limited work, the material is highly sorbed when the soil is quite dry.

3. Soil Type -- Soil type is a very important factor in diffusion of soil fumigants. Experience has shown that heavy clay soils are not suitable for fumigation with the fumigants now available. The reason for this is probably due to sorption, either because of increased active surface area of the soil particles, or the blocking of pore spaces by soil moisture. At our laboratory we measure the suitability of a soil for fumigation by the moisture equivalent. We have found that where soils have a moisture equivalent of 25 percent or more, the dosage must be increased to be effective. In our experimental work, we determine moisture equivalent of all prospective plot sites before applications are made. In general, we avoid soils approaching a moisture equivalent of 30 percent. The volcanic soils of Hawaii have a M.E. of 32 percent and the best results are secured at the rate of 80 gallons of D-D per acre, which is three to four times the dosage required for soils of M.E. of 20 percent or less which are most desirable for fumigation.

4. Compaction -- For best results, soil to be fumigated should be well worked as deep as practicable. Sub-soiling with chisels 10 to 12 inches apart or deep plowing is desirable. The soil should be pulverized as much as possible as fumigants will not penetrate clods, especially if on or near the soil surface. The soil preparation should be as near seed bed condition as possible. As stated in Hansen's[3] paper, the porosity of soil is greatly reduced by compaction and the reduced porosity in turn reduces the dispersion of the chemical.

5. Sorption -- Very little is known concerning sorption of chemicals by soils. Work at our laboratory and by Crafts and others has shown that chemicals are sorbed to a greater degree by dry soil than moist; although Hansen[3] says that EDB is sorbed least at wilting point and to a greater extent as the moisture content is increased or decreased. This is possibly due to two different types of sorption. In dry soil the material would be held by soil particles and perhaps in the wet soil the chemical would be taken up in the water, depending on solubility. The effect of sorption on dispersion of soil fumigants is not well understood. In theory, a certain degree of sorption is probably desirable although a high degree would reduce dispersion and increase phytotoxicity. Peat soils, which are high in organic matter, are not favorable for fumigation due to a high degree of sorption. This difficulty has been somewhat overcome in muck soils of Indiana and Michigan by closer spacing of chisels and increased dosage rates.

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[3] Hansen, W. J. and R. W. Nex. 1953. Diffusion of ethylene dibromide in soils. Soil Science 76 (3). Sept.

New Materials

There are several experimental new materials being tested at present. Although the chemical nature of some of these materials has not been divulged, the activity is fairly well known. As far as we are aware, none of these materials is proven to be more effective than D-D or EDB with the exception of an experimental Shell product known as OS 1897. This material is approximately ten times more effective than D-D and is comparatively non-toxic to living plants. The mode of action on nematodes is not known but is believed to be different than for other materials now in use. Evidently, this material is a very slow nematode poison and is residual in the soil for several weeks. This material is the most effective material tested by our laboratory. The main difficulty is that seed germination has been depressed in some instances by this material. It has been used both by injection and emulsion on living plants, without damage, at well over nematocidal dosages.

Preliminary field results have shown this material to be quite effective on cyst nematodes at 2.5 to 5 gallons per acre.

In row application for cotton and tomatoes, very satisfactory root knot nematode control has resulted with as low as 0.5 to 1 gallon per acre.

Practical Application of Soil Fumigants

Commercially, soil fumigants are applied as liquids either by chisel injection or by dripping or spraying in front of mold board plows. In both methods, the metering is usually done by a pressurized manifold with an orifice in each line. This method requires a pump, CO_2 tank, or some other method of forcing the chemical through the orifices. Where only one or two lines or outlets are used, a gravity flow method has been developed by the Insect Control Service of Charlotte, North Carolina. The metering is accomplished by a regulating valve in each line. This valve can be opened or closed for desired dosage.

At our Modesto Laboratory it was necessary to develop equipment for applying chemicals at very low dosages, 1 gallon or less per acre on 12 inch spacing. To do this, a system was developed whereby the metering was accomplished by capillary tubing. This was at first accomplished by using short lengths of small bore glass tubing, but considerable trouble was experienced due to plugging of the small openings. Finally, the possibility of using lengths of Saran tubing in the same manner as a capillary tube was tried. It was found that this tubing could be used as an orifice providing a constant head vessel was used. The dosage was found to vary indirectly with the length of the tubing and directly with the effective head. This method of metering is very effective in that no plugging results even with very low dosages due to comparatively large openings in the tubing. The main difficulty is that if more than one outlet or tube is used per vessel, a means of cutting off each line is necessary to insure proper functioning. This can be done either with multiple valves or a valve on each line.

Row and Solid Applications

For close planted crops, such as most vegetables, or where a high degree of control is necessary, a solid application is used. As described above, this is accomplished by pressurized manifold with chisels spaced 12 inches apart.

Row applications are made on wide planted crops such as tobacco, cotton, tomatoes, and melons. In some cases only the planting site or the row is treated for grapes and trees. For perennial plantings, the solid application is considered to be most desirable, however, because of the long period over which the plants are grown. In row application, the amount of fumigant used can be greatly reduced. For example, row applications for tobacco require less than that required for solid application. Raski and Allen[4] reported on control of root-knot nematode of cotton by row application of D-D. In this experiment, the application of from 4 to 12 gallons of D-D per acre increased the yield by 1/2 to 1 bale of lint cotton per acre over the untreated. The nematode control ranged from 25 percent control at 4 gallons per acre to 80 percent control at 12 gallons.

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[4] Raski, D. J., and Allen, M. W. 1953. Control of root knot nematode of cotton. Plant Dis. Reptr. 37 (4).

FACTORS AFFECTING RESULTS WITH SOIL FUMIGANTS

C. E. Dieter

Soil fumigation is the application of volatile chemicals to the soil for the control of undesirable soil-borne organisms that interfere with plant growth. These fumigants must therefore diffuse throughout the soil mass, and remain there at a toxic concentration for a sufficient period to give satisfactory control. They should leave no persistent residues that are toxic to the subsequent crop. To accomplish this they must be applied under the right conditions and by the correct method.

In practice, however, soil fumigants are often necessarily applied when needed and at the convenience of the operator. They are rarely applied in compliance with all of the recommended conditions. The results obtained may range from poor to good as reflected by pest control or plant growth, depending upon how near the actual conditions at time of application approached the recommended ideal.

FIGURE 1. Control of the nematode-Fusarium wilt complex of cotton with a soil fumigant applied in the row. Note good cotton on right and left while the two center rows are poor due to faulty application.

Chemicals for the control of soil-borne plant parasitic nematodes have come into extensive use in recent years, due largely to the development of ethylene dibromide and dichloropropene-dichloropropane mixture, which can be used economically for large scale field applications. These materials will control insects and nematodes, and indirectly certain soil-borne diseases. Chloropicrin and methyl bromide are used in small scale specialized operations for the control of insects, nematodes, weeds, and certain soil-borne diseases. There are still many nematode problems for which satisfactory control measures have not been developed, such as control of nematodes around living plants and in heavy soils. With a better understanding of the factors involved in fumigation more progress should be made in the future.

This report is an attempt to familiarize those interested in the control of nematodes and other soil-borne pests with the importance of some of the conditions and factors that may influence the results obtained from applications of soil fumigant materials. It is important that these conditions and certain other factors be noted and considered not only at the time of application but throughout the growing season in order to determine the value and limitations of a soil fumigant.

The literature dealing with the effect of soil conditions on the effectiveness of soil fumigants is difficult to summarize due to the diverse conditions under which the work has been conducted. The interaction of the various factors affecting soil conditions is important, but seldom considered. A review of the literature however indicates that investigators are in general agreement on the conditions essential for satisfactory fumigation. These conditions are as follows: 1) sandy soils can be treated more successfully than clays or highly organic types; 2) soil at time of application should be in good tilth; 3) plant roots of the previous crop should be decomposed and the trash should be well buried; 4) moisture should be moderate and uniform throughout the soil mass; 5) soil temperature does not appear critical when between 50° and 85°F, however, the higher temperatures in this range are more desirable, particularly for chloropicrin; 6) the immediate leveling and compacting of the soil surface is necessary to seal in the fumigant following treatment with dichloropropene-dichloropropane mixture and ethylene dibromide; 7) a gas-proof cover is necessary when using methyl bromide and a gas-proof cover or water seal is desirable when using chloropicrin. It is interesting to note that the conditions required for satisfactory results with soil fumigants are essentially the same as those necessary when using steam in buried tile lines for soil sterilization. These conditions are necessary to give an even distribution of the steam throughout the soil and they are even more critical for satisfactory results with chemicals for soil treatments. The fumigants must travel from the point of application throughout the soil mass by gaseous diffusion in the soil atmosphere. The chemicals apparently must be dissolved in the soil moisture around the pests in order to control them.

Field observations have shown that the sandy soils and lighter loams are more readily fumigated than other types. High soil moisture (10 to 15 percent on dry weight basis) and low porosity appear more necessary with ethylene dibromide than with dichloropropene-dichloropropane mixture. Clay soils can be satisfactorily treated if they are in a physical condition that will permit the satisfactory diffusion of the fumigant. High soil moisture (100 to 200 percent on a dry weight basis) is essential for satisfactory results with the highly organic soils, which have extremely high moisture equivalents. Moisture apparently functions in reducing porosity and satisfying the high sorptive capacity of these organic soils. Larger dosages of fumigants are required for consistent results on organic soils than on mineral soils.

Extremely dry soils apparently cannot be successfully treated due to the sorption and the too rapid escape of the fumigant. Conditioning of the pests by soil moisture may also be involved. Excessive soil moisture interferes with the diffusion of the fumigant, as indicated by poor root-knot nematode control in root crops such as carrots. When downward diffusion is apparently limited by the height of the soil water table the tips of carrots are severely galled while the upper portions are clean. Lateral diffusion is also inhibited. Wireworms, however, have been controlled in wet soils, possibly because they were in the upper soil layer. Even when methyl bromide is applied to a dry soil under a gas-proof cover poor results are obtained. A wet soil will prevent the penetration of the fumigant, and will also result in poor control and often plant injury.

The fumigant materials generally must be dissipated from the soil before satisfactory plant growth can be obtained. It appears that conditions essential for satisfactory treatment are not necessarily suitable for aeration. Soils should be fairly loose and dry for proper aeration. The fumigants, if not dissipated from the soil surface into the air, are mineralized and remain in the soil as various residual breakdown products. Under certain conditions they may be phytotoxic. Heavy rains following treatments often necessitate prolonging the aeration period before planting. When the fumigant is present in the upper soil surface reduced stands may result. When it is present at deeper levels plant toxicity symptoms may be delayed and sprangled roots may occur on root crops.

It appears that some so called failures of soil fumigants as measured by plant growth response are due to the fact that certain desirable organisms are temporarily reduced. For example, under certain conditions onion yields are reduced because of early maturity attributed to high ammonia nitrogen which upsets the nitrogen-carbohydrate ratio. This reduction may be in direct proportion to the inhibition of the nitrifying bacteria. It is indicated that ammonia injury can be corrected with applications of nitrate nitrogen or by increasing the available calcium in the soil. The stunting and chlorosis of pine seedlings which sometimes follows seedbed treatments with methyl bromide has been associated with the reduction of the mycorrhiza which are necessary for the normal growth of conifers.

It may not be desirable in many instances to completely disinfest the soil but only to temporarily reduce the pests in order to allow the plant to become well established. It is often difficult to correlate certain crop yield increases following fumigation with the high nematode

populations present at the end of a growing season as compared to the low yields and the low populations present in untreated areas.

When soil fumigation results are measured by plant growth or crop yields and not by actual pest control, plant tolerance to the fumigant cannot and should not be ignored. Yields might be more a measure of phytotoxicity than of pest control. This is an especially important point to be considered when only a single dosage is used in a soil fumigation experiment, since the effects of other dosages are not available for comparison.

It has been found necessary to correct plant nutrient deficiencies or imbalances and soil reaction for a particular crop before satisfactory results can be obtained from soil fumigant applications. In some instances it also may be necessary to change the fertilizer recommendations for certain crops when the soil is fumigated. It has been found that the ammonia nitrogen balance is important for crops such as potatoes and tomatoes following fumigation with ethylene dibromide. High ammonia nitrogen however appears satisfactory for tobacco and pineapple, which generally show excellent response following fumigation. Good cultural practices, as well as disease and insect control must be observed in order to obtain maximum benefits from soil fumigation.

More than one nematode species often is encountered in a problem field. Because of the differences in the susceptibility of the various species to a given fumigant material one should know the pests involved. The root lesion, stubby root, or other species of nematodes, for instance, may not be controlled at the dosages used for the control of the root-knot nematodes.

The various fumigants also show a certain specificity as regards the control of different nematode species. For example, ethylene dibromide is considered more effective for the control of the potato rot and sting nematodes than dichloropropene-dichloropropane mixture. The latter is more effective against the encysted stages of such species as the sugar beet nematode. The larvae of the root-knot nematode are readily controlled by both; however, dichloropropene-dichloropropane mixture is considered more effective against the eggs. Thus the nematode species as well as the various life stages involved may determine the fumigant and dosage to be used for a particular problem. Methyl bromide seems to be effective over a wider range of pests than the other fumigants; however, the dosages used are generally higher.

The time of sampling for nematodes is very important not only for determining the presence of a nematode problem but also for evaluating soil fumigation results. In Michigan the root lesion and stubby root nematodes in some situations are found abundant in spring and early summer, but scarce or absent later in the season. It is felt that this may be associated with soil temperature and moisture conditions.

It has been found that nematodes are seldom uniformly distributed but generally occur in scattered areas throughout the field. Unless experimental plots are properly randomized significant results often cannot be shown because of extreme variations between replicates even though yield differences between treatments may be large.

The exact formulation of the fumigant used should be known and applications should be made on the basis of the active ingredient. Ethylene dibromide formulations, for example, have been used under about a dozen different designations. It has been found desirable to report results in terms of the actual amount of ethylene dibromide applied.

The fumigant applicator, regardless of type, should be in first class working condition so uniform applications can be made throughout a series of experiments. To avoid plugged nozzles a good line filter is an essential part of any field applicator. The machine must be calibrated for each material, for often various formulations of the same chemical have different rates of delivery under similar conditions. The calibration should also be checked frequently to be sure proper dosages are being applied.

Consideration of all of these factors is important when comparing two fumigants such as dichloropropene-dichloropropane mixture and ethylene dibromide. Satisfactory results may be obtained in one instance and then under apparently similar conditions one or both of them may fail. It must be recognized, however, that each fumigant has different and specific physical and chemical properties and each behaves differently under a given set of conditions. However, at times all soil fumigants appear equally effective. The common range for optimum effectiveness is apparently quite narrow and this may account for the many variations in the results obtained from applications made under conditions that appear satisfactory. These conditions as well as the properties of the chemicals are important considerations when evaluating new soil fumigant chemicals under diversified field conditions.

The past crop history of a field should be known and considered in a soil fumigation program. Certain crops may allow for the buildup of a large population of nematodes and larger dosages of a fumigant may be required to reduce the population enough for satisfactory results.

Woody type roots will protect nematodes, and a longer time must be allowed for these roots to decompose before fumigation than for the softer more succulent type roots. There are indications that large amounts of undecomposed organic matter turned under just before fumigation interferes with the action of the fumigant. Another factor is that undecomposed roots may protect the nematodes inside them from the fumigant.

The subsequent crops also must be considered in the evaluation of soil fumigation results. For instance, nematode-resistant crop varieties have proved to be very useful aids in crop production in certain areas but often this resistance is expressed only against a certain nematode complex. This resistance may break down under high nematode populations or in another location where the nematode complex is different. The use of so-called resistant varieties, supplemented with soil fumigation, is often highly beneficial. The dosage of the fumigant used will depend on the severity of the nematode population and on the susceptibility of the crop to the pests. Perennial crops which need a longer period of protection require more complete initial nematode control than annuals and thus require higher dosages.

The many factors which influence the results from the application of soil fumigants make it necessary to study these chemicals in various areas in order to determine which fumigant should be used as well as the best conditions and methods of application for satisfactory results. Only when the effect of these factors and their interaction on the results obtained from application of soil fumigants are understood can a sound nematode control program be developed.

THE DOW CHEMICAL COMPANY

THE NEMATODE COMPLEX IN SOUTHERN GEORGIA

John H. Machmer

In dealing with Baermann separable nematodes one is constantly confronted with a complex both tedious to work with and difficult to separate into its components. No longer may we speak of "nematodes" and mean only the root-knot disease. Even more, we must not now speak only of stubby root, coarse root, root lesion, etc., nematode diseases. It is necessary to evaluate all of these diseases, their symptoms, and the associated nematode kinds quantitatively, when rating a plant, plot, field, or crop region. It has become our practice recently to rate root collections by scoring symptoms of the several diseases. However, in practical soil fumigation work root-knot symptomatology still remains an excellent and widely applicable diagnostic method.

Observations are reported chiefly on the following nematodes: Sting (Belonolaimus), dagger (Xiphinema), true spiral (Helicotylenchus), other spiral (Rotylenchus spp.), ring (Criconemoides), stubby (Trichodorus and Paratylenchus), meadow (Pratylenchus spp.) and root-knot (Meloidogyne spp.). These are the parasitic nematodes usually and abundantly encountered. Besides these eight groups possibly six to ten other genera could have been scored. It is problematical whether this could be done in routine work.

Most of you can well remember when the root-knot nematodes only were recognized, and those as a single form. Very often, nematodes were not considered at all..

Although the Baermann method has long been used by plant nematologists its recent application to crop-nematode evaluation methods now makes it to the nematologist what the culture plate has long been to the plant pathologist. Perhaps many nematological opinions based on other than the Baermann technique are or should be reconsidered.

The material presented in tabular form herewith is entirely preliminary, and is intended merely to illustrate the variety and complexity of the problems encountered and the intensive work required in their study.

Table 1. Predominance of ring nematodes in the nematode complex of the Georgia peanut region, as shown by occurrence in samples from the sources indicated, collected from June to October, 1953.

Nematode	Average number of nematodes per standard Baermann sample of 15 cu. in.				Total nemas scored and counted	Sample frequency
	Region 28 samples 25 farms 14 counties	Station 43 samples 27 plots	Experiment 64 samples 8 treatments	All sources 135 samples 53 locations		
PARASITIC						
Sting (Belonolaimus)	5[d]	0	0	1(-)	130	2
Dagger (Xiphinema)	59	5	0	14	1,850	19
Spiral, true (Helicotylenchus)	8	4	--[a]	3	360	8
Spiral, other (Rotylenchus spp.)	22	8	51	31	4,240	57
Ring (Criconemoides spp.)	162	132	107	126	17,060	112
Stubby (Trichodorus, -- and Paratylenchus or "Pin")	23	15	34[a]	25	3,440	65
Meadow (Pratylenchus spp.)	48	55	--[a]	28	3,720	70
Root-knot (Meloidogyne arenaria)	121[b]	0	0	25	3,400	5
Total parasitic	448	219	192	253	34,200	
Percent Ring	36	60	56	50	50	
SAPROPHYTIC AND PREDACEOUS						
Dorylaimus and Mononchus	274	247	119	192	25,900	120
SAPROPHYTIC, SCAVENGER, AND MISCELLANEOUS Not Scored[c]	603	594	438	522	70,460	134
Total all Nematodes	1325	1060	749	967	130,560	135
Percent Ring					13	

[a] True Spiral and Meadow combined with Stubby under "Experiment".

[b] Root-knot from three farms 5 samples only, in the upper peanut area in the Chattahootchee Valley.

[c] Chiefly Diploscapter, Diplogaster, Acrebeloides, Rhabditis, miscellaneous, saprophytic, Cephalobus, and unscored or unidentified parasitic including Aphelenchs, etc., besides Tylenchs. Of these Rhabditis and Acrebeloides occur most commonly.

[d] Two samples, one field only.

Table 2. Nematodes associated with cotton in southern Georgia. Number of nematodes obtained from 15-cu. in. standard Baermann samples collected from 16 experiments and from 20 farms in 11 counties, total 41 samples (360 hills).

Nematode	Total no. estimated from 10% scores	Average number per sample all 41 collections	Number samples containing	Average number in samples containing	Percent of total parasitic
Total	56,930	1389	-	-	-
Sting[a]	480	12	3	160	2.1
Dagger	1,800	44	19	95	7.8
True spiral	2,740	67	12	228	11.9
Other spiral	580	14	5	116	2.1
Ring	670	16	17	39	2.1
Stubby	3,500	85	33	106	10.4
Meadow	3,460	84	33	105	10.7
Root-knot[b]	8,620	210	21	411	37.6
Dorylaims and mononchs	10,480	256	40	262	-
Other miscellaneous	23,560	575	41	575	-

[a] Late season collection may account for relatively small number of sting nematode.

[b] Descending order of prevalence: root knot, stubby, meadow, true spiral, dagger.

Table 3. Nematodes associated with 16 common weeds, with kind and severity of accompanying root symptoms[a].

Host	Total no. nematodes (estimated from 10% scroes)	10% level scores[a]							Root symptoms and severity[b]		
		Dagger	Ring	Stubby	Meadow	Root knot	Miscellaneous: Dorylaimus Mononchus	Miscellaneous: Other	Root-knot	Coarse root	Root lesion
Aster ericoides	920	2	1	1	4	12	33	39	Z	Z	L
Diodia teres	310	0	1	1	0	2	9	18	Z	M	M
Ambrosia artemisiifolia	1540	1	1	0	6	25	52	71	L	Z	H
Aplopappus divaricatus	1250	0	0	2	4	22	36	61	L	Z	L
Gerardia tenuifolia	2160	3	3	4	16	44	57	89	Z	Z	M
Hypericum gentianoides	640	1	1	0	0	12	25	25	Z	Z	M
Aristida	5260	3	13	6	39	52	197	216	L	L	H
Andropogon virginicus	2530	2	8	6	11	25	77	124	M	L	H
Cyperaceae (Cyperus, large)	3630	0	15	8	7	30	100	203	H	L	Z
Eupatorium tenuifolium	2520	3	3	2	9	21	84	130	Z	Z	L
Richardia scabra	1270	0	0	2	2	25	29	69	Z	Z	Z
Heterotheca subaxillaris	2380	1	3	1	5	20	69	139	Z	Z	Z
Paspalum sp.	1670	0	1	2	5	6	63	90	L	Z	Z
Digitaria sanguinalis	5300	9	13	13	24	124	141	206	H	L	L
Cyperaceae (Cyperus, small)	4820	1	4	6	9	16	204	242	Z	Z	Z
Cynodon dactylon	2960	2	1	12	11	65	82	123	L	L	L
Total at the 100% level	39160	280	680	640	1520	5010	12580	18450			

[a] Average scores of 2 15-cu. in. Baermann samples (20 hills) processed 40 hours, September 1953.

[b] Z = None; L = light; M = moderate; H = heavy.

Table 4. Nematode control vs. fertilizer application as means of prolonging productive period of Louisiana white clover in the southern Georgia Native Flat Woods Range[a]. Total number of nematodes (from 10 percent evaluation levels) per average 15 cu. in. Baermann sample per treatment plot, thrice replicated. (November 1952 to September 1953).

TREATMENT Time of collection	No. samples	Number of nematodes								
		Sting	Dagger	True Spiral	Other spiral	Ring	Other parasitic[b]	Dorylaims and Mononchs	Miscellaneous	Total (average) per sample
NOT FUMIGATED										
Preplant collection Nov. 19, Nov. 26, Dec. 9, 1952	30	53	82	44	41	19	64	99	242	669
FUMIGATED										
Preplant collection Dec. 9, 1952	6								19	19
NOT FUMIGATED										
Growth period Apr. 1, May 18, June 22, 1953	18	12	116	5	204	9	--[c]	153	441	944
Dormant period Sept. 21 (after 6 weeks grazing Aug. 1-Sept. 21, 1953)	6	28	147	88	377	0	64	283	578	1564
FUMIGATED										
Growth period (as above)	18							27	363	389
Dormant period (as above)	6				15		20	177	975	1187
WITH FERTILIZER (Fumigated and not fumigated)										
Growth period (as above)										
100 lbs/A 16 X	18	8	63	5	113	6	--[c]	89	411	702
1600 lbs/A 1X	18	3	52	0	85	4	--[c]	90	393	632

a In cooperation with RF Suman, Range Conservationist, U. S. Southeastern Forest Experiment Station.

b Including Stubby, Meadow, and others.

c Very few, calculated with miscellaneous.

Table 5. Nematode control vs. fertilizer application as means of prolonging productive period of Louisiana white clover in the southern Georgia Native Flat Woods Range[a]. Vigor ratings and weed control during growth period (April to September 1953).

Treatment	Vigor ratings[b] (average of 6)			Percent growth in plot area	
	April 1	May 15	Sept. 21[c]	Living clover June 22	Weeds Sept. 21
NOT FUMIGATED	1.7	1.7	1.0	48	13
FUMGATED	3.3	3.6	3.6	85	6
FERTILIZER 16 X	2.7	2.5	2.2	68	11
FERTILIZER 1 X	2.3	2.8	2.5	66	9

a In cooperation with RF Suman, Range Conservationist, U. S. Southeastern Forest Experiment Station.

b 1 = poor to 4 = excellent

c After 6 weeks grazing, Aug. 1 to Sept. 21.

GEORGIA COASTAL PLAIN EXPERIMENT STATION AND NEMATOLOGY SECTION, HORTICULTURAL CROPS RESEARCH BRANCH, AGRICULTURAL RESEARCH SERVICE, U. S. DEPARTMENT OF AGRICULTURE, TIFTON, GEORGIA